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56. Prior art cited:

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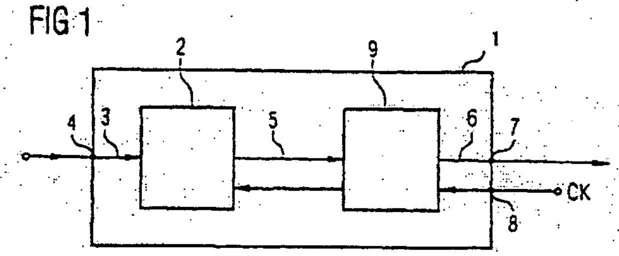
The following information has been taken from the documents submitted by the applicant.

Examination requested in accordance with § 44 of the Patent Code.

54. Integrated circuit with an A/D or D/A/ converter with electrical isolation

57. This invention relates to an integrated circuit which contains an analog-to-digital converter (ADC) or a digital-to-analog converter (DAC) and an analog and digital signal path connected to the converter. The digital signal path of the integrated circuit also contains a device for electrical isolation.

FIG 1



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Description

Integrated circuit with an A/D or D/A converter with electrical isolation.

This invention relates to an integrated circuit which contains an analog-to-digital converter or a digital-to-analog converter as well as an analog and a digital signal path connected to said converter.

Analog-to-digital converters and digital-to-analog converters are known from the book entitled "Digitale Verarbeitung analoger Signale" *[Digital Processing of Analog Signals]* by Samuel D. Stearns, 4th Edition, published by R. Oldenbourg Verlag, Munich and Vienna, 1988, pp. 69 to 75. An analog-to-digital converter digitizes the sampled values of an existing time function and delivers the input signals for a digital processor. A digital-to-analog converter works reciprocally to the analog-to-digital converter. It converts a coded set of digital values into a varying analog voltage. During the analog-to-digital conversion, quantification errors, tracking errors and jitter errors can occur which have an adverse effect on the accuracy of the conversion. Attempts to keep the effects of various electrical or mechanical error sources in digital-to-analog converters low have included the selection of precision components, precision power supplies, a narrowing of the operating temperature range etc.

Furthermore, analog-to-digital converters and digital-to-analog converters are also known from the book entitled "Halbleiter-Schaltungstechnik" *[Semiconductor circuit technology]* by U. Tietze and Ch. Schenk, published by Springer Verlag, 1990, pp. 751 to 790. A converter of this type can be realized by using the parallel process, the successive approximation method and the pulse count method. The above mentioned converters are generally available in the form of integrated circuits, such as C-MOS circuits, for example.

In analog-to-digital and digital-to-analog converters of this type, the analog and the digital side are each related to different reference voltages, which means that voltage differences occur. These differences must be compensated for appropriately. This compensation is achieved in integrated circuits of the prior art by electrically

isolating the data channels from the converter components by discrete components located upstream or downstream of the converter component. For an electrical isolation of this type, optical couplers, inductive or capacitive couplings are used.

DE-197 18 420 A1 discloses an integrated data transmission circuit with electrical isolation between the input and output circuits. Binary signals are fed to this circuit on the input side which are transmitted by the use of a magneto-sensitive coupling element which is located inside the integrated data transmission circuit, and are made available at the output of the integrated data transmission circuit in the form of binary output signals.

The object of the invention is to develop an analog-to-digital or digital-to-analog converter which is realized in the form of an integrated circuit so that the overall circuit in which it is located has a reduced power consumption.

The invention teaches that this object is accomplished by an integrated circuit with the features disclosed in Claim 1. Advantageous configurations and developments of the invention are described in the subclaims.

The advantages of the invention are, among other things, that as a result of the integration of the electrical isolation device into the digital signal path provided inside the integrated circuit, an A/D converter or D/A converter realized in the form of an integrated circuit with the features claimed by the invention consumes significantly less energy than a converter with upstream or downstream electrical isolation realized by means of discrete components. Moreover, a converter as claimed by the invention requires less space for its realization, which promotes the miniaturization of A/D or D/A converters. Furthermore, higher data rates can be achieved by means of a converter of this type. Converters of this type can also be manufactured more economically than converters of the prior art. The invention makes available a new class of components which combine the functions of an A/D or D/A/ converter and a contactless data transmission circuit. This principle can be used on all modern A/D and D/A/ converters.

Additional advantageous characteristics of the invention are explained in greater detail below with reference to the exemplary embodiments that are illustrated in the accompanying figures, in which:

Figure 1 is a block diagram of an integrated circuit which contains an analog-to-digital converter,

Figure 2 is a block diagram of an integrated circuit which contains a digital-to-analog converter, and

Figure 3 is a block diagram of an integrated circuit which contains a sigma-delta converter as an analog-to-digital converter.

Figure 1 is a block diagram of an integrated circuit 1 which contains an analog-to-digital converter 2. The analog signal to be converted is fed to the input 4 of the integrated circuit 1, and said signal is then fed from the input 4 of the integrated circuit 1 via an analog signal path 3 to the analog-to-digital converter 2. At its output, the analog-to-digital converter 2 makes available a digital signal that has a digital value which is fed via a digital signal path 5, 6 to the output 7 of the integrated circuit 1.

In the digital signal path 5, 6 there is a device 9 for electrical isolation, which is consequently located downstream of the analog-to-digital converter 2. The device for electrical isolation has, on the input side, a conductor loop by means of which the signal, which is present in digital form, is transported. As a result of this digital signal, a magnetic field is generated in the area surrounding the conductor loop which varies as a function of the digital signal. This varying magnetic field is detected by a magnetic field detector which is isolated from the conductor loop by an isolator, but is located in the area of the above mentioned magnetic field. The signal detected by the magnetic field detector is made available at the output 7 of the integrated circuit 1 in the form of a digital signal which is electrically isolated from the input side.

Inside the analog-to-digital converter 2, a digital clock signal is required. This signal is fed to the integrated circuit by means of an input 8 and forwarded by means of the electrical isolation device 9 to the analog-to-digital converter 2. Consequently, inside the electrical isolation device 9 there are two transmission channels, one of which is a data transmission channel and the other of which is a clock transmission channel.

The magnetic field detector of the electrical isolation device 9 can be realized in the form of a Hall-type element. The above-mentioned magnetic field detector can also be an AMR (anisotropic magnetic resistance) sensor, which reacts to a varying

magnetic field with a resistance variation. AMR sensors of this type have a permalloy layer.

To improve the sensitivity of the magnetic field detector, it can also be realized in the form of a GMR (giant magnetic resistance) sensor. Sensors of this type have a combination of three layers, two of which are made of magnetically soft material and one of which is made of magnetically hard material.

A further improvement of the sensitivity of the magnetic field detector can be achieved by realizing the detector in the form of a TMR (tunneling magnetic resistance) sensor. In this sensor, a layer made of a magnetically hard material is replaced by an isolating layer.

Figure 2 is a block diagram that illustrates an integrated circuit 10 which contains a digital-to-analog converter 15. The digital signal to be converted is fed to the input 11 of the integrated circuit and is then fed from the input 11 of the integrated circuit 10 via a digital signal path 12, 14 to the digital-to-analog converter 15. This latter converter makes available, at its output, an analog signal which is forwarded via an analog signal path 16 to the output 17 of the integrated circuit 10.

In the digital signal path 12, 14 there is a device 13 for electrical isolation, which is consequently upstream of the digital-to-analog converter 15. The device 13 for the electrical isolation itself is constructed just like the device 9 for electrical isolation described above in connection with Figure 1. The digital signal made available at the output of the device 13 for electrical isolation, which is a digital signal that is electrically isolated from the input side, is fed via the digital signal path 14 to the digital-to-analog converter 15. The latter converter converts the above mentioned signal, using a digital clock signal, into an analog signal which - as described above - is forwarded via the analog signal path 16 to the output 17 of the integrated circuit.

The digital clock signal required in the digital-to-analog converter 15 is generated outside the integrated circuit 10 and is fed to it via the connection 18. In the integrated circuit 10, the digital clock signal travels via the device 13 for electrical isolation in the form of an electrically isolated digital clock signal to the digital-to-analog converter 15. Consequently, inside the device 13 for electrical isolation, there are two transmission

channels, one of which is a data transmission channel and the other of which is a clock transmission channel.

Figure 3 shows a block diagram of an integrated circuit 20 which contains a sigma-delta converter as the analog-to-digital converter. This converter generates a 1-bit data stream, the logic level of which depends on whether the signal to be converted is greater than or less than a signal obtained on the basis of this comparison and then integrated.

An analog input signal is fed by means of the input 27 to the illustrated integrated circuit 20. This signal is forwarded from the input 27 to the sigma-delta converter which is located inside the integrated circuit 20. This sigma-delta converter has a subtraction stage 21 in which the signal fed back by means of a feedback path 24, which is converted back into an analog signal in a digital-to-analog converter 29, is subtracted from the input signal. The output signal of the subtraction stage 21 is integrated in an integrator 22 and is fed by it from the comparator 23. At this output, which forms the output of the sigma-delta converter, the above mentioned 1-bit data stream is available as the digital signal.

This signal - as described above - is subjected to a digital-to-analog conversion in the feedback path 24 and is fed as the subtrahend to the subtraction stage 21.

The 1-bit data stream is also guided to a device 25 for electrical isolation. There - as in the exemplary embodiments described above - a dual-channel magnetic transmission takes place in which the digital signal and the clock signal required for the analog-to-digital conversion is transmitted in an isolated manner. The digital output signal of the device 25 for electrical isolation is forwarded via a digital filter 26 which is also a component of the integrated circuit 20 to the output 28 of the integrated circuit 20.

In this embodiment, too, both an analog-to-digital conversion and an electrical isolation take place in one and the same integrated circuit. Compared to the analog-to-digital converters of the prior art, this results in a saving of power, space and manufacturing costs and makes possible a higher data rate.

Claims

1. Integrated circuit which contains an analog-to-digital converter or a digital-to-analog converter and an analog and a digital signal path connected with said converter, **characterized by the fact** that it has a device (9, 13, 25) for electrical isolation in the digital signal path.

2. Integrated circuit as claimed in Claim 1, characterized by the fact that it contains an analog-to-digital converter (2) connected on the input side with an input (4) of the integrated circuit (1), which converter makes available at its output a digital signal, that the device (9) for electrical isolation is connected to the output of the analog-to-digital converter (2) and that the device (9) for electrical isolation is connected with an output (7) of the integrated circuit (1).

3. Integrated circuit as claimed in Claim 2, characterized by the fact that the analog-to-digital converter is a sigma-delta converter (21, 22, 23, 24, 29).

4. Integrated circuit as claimed in Claim 3, characterized by the fact that the sigma-delta converter has a subtraction stage (21), an integrator (22) connected with its output, a comparator (23) connected with the output of the integrator and a feedback path (24) that begins at the output of the comparator (23), in which feedback path there is a digital-to-analog converter (29) and the output of which is connected to the subtraction stage (21), and that the device (25) for electrical isolation is connected with the output (28) of the integrated circuit (20).

5. Integrated circuit as claimed in one of the Claims 2 to 4, characterized by the fact that the output of the device (25) for electrical isolation is connected via a digital filter (26) with the output (28) of the integrated circuit.

6. Integrated circuit as claimed in Claim 1, characterized by the fact that it contains a digital-to-analog converter connected on the output side with an output (17) of the

integrated circuit (10), that the device (13) for electrical isolation is connected to the input of the digital-to-analog converter (15) and that the device (13) for electrical isolation is connected on the input side with the input (11) of the integrated circuit (10).

7. Integrated circuit as claimed in one of the preceding claims, characterized by the fact that the device (9, 13, 25) for electrical isolation has two transmission channels, one of which is a data transmission channel and the other of which is a clock transmission channel.

8. Integrated circuit as claimed in one of the preceding claims, characterized by the fact that the device for electrical isolation has a conductor loop on the input side and a magnetic field detector element on the output side.

9. Integrated circuit as claimed in Claim 8, characterized by the fact that the magnetic field detector element is a Hall element.

10. Integrated circuit as claimed in Claim 8, characterized by the fact that the magnetic field detector element is an anisotropic, magneto-sensitive element (AMR).

11. Integrated circuit as claimed in Claim 8, characterized by the fact that the magnetic field detector element is a giant magneto-sensitive *[Translator's Note: sic - should be giant magnetic resistance]* (GMR) element.

12. Integrated circuit as claimed in Claim 8, characterized by the fact that the magnetic field detector is a tunneling magnetic resistance (TMR) element.

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